# Innovation and productivity in services: Empirical evidence from Latin America

UNU-MERIT Working Paper Series

#2014-068

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**Gustavo Crespi, Ezequiel Tacsir and Fernando Vargas**

**Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)**
email: info@merit.unu.edu | website: http://www.merit.unu.edu

**Maastricht Graduate School of Governance (MGSoG)**
email: info-governance@maastrichtuniversity.nl | website: http://mgsog.merit.unu.edu

Keizer Karelplein 19, 6211 TC Maastricht, The Netherlands
Tel: (31) (43) 388 4400, Fax: (31) (43) 388 4499

**INNOVATION AND PRODUCTIVITY IN SERVICES:**

**EMPIRICAL EVIDENCE FROM LATIN AMERICA**

Gustavo Crespi[1], Ezequiel Tacsir[1,2], and Fernando Vargas[1,2]

# Abstract*

This paper analyses and compares the determinants of innovation in the service industry and its impact on labour productivity at the firm level in three countries of Latin America (Chile, Colombia, and Uruguay). The main findings show that, similar to what is observed in the manufacturing industry, service firms that invest the most in innovation activities are more likely to introduce changes or improvements in their production process and/or product mix, and those firms that innovate have higher labour productivity than non-innovative firms. Size was found to be a less relevant determinant of innovation in services than in manufacturing, suggesting that the need for infrastructure and associated sunk costs are lower in services. Conversely, cooperation was found to be far more important for innovation in services than in manufacturing, in line with the more interactive nature of innovation in services. Yet, large differences in statistical significance and size of the coefficients of explanatory variables among the countries studied suggest that the framework conditions where a firm operates have an important role in innovation decisions.

**JEL Codes: O12, O14, O31, O33, O40, O54**

**Keywords:** Innovation, productivity, services, developing countries, Latin America, innovation surveys

1 Competitiveness and Innovation Division, Institutions for Development, Inter-American Development Bank – E-mail: gcrespi@iadb.org

2 United Nations University and Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT), Maastricht, the Netherlands – E-mail: tacsir@merit.unu.edu, vargas@merit.unu.edu

* This work is part of the research project RG-K1230 "Productivity and Innovation in Services: The Role of Public Policies" coordinated by the Competitiveness and Innovation Division of the Inter-American Development Bank (IDB) and the International Development Research Centre (IDRC), and has been published as an IDB Technical Note. The IDB Technical Notes encompass a wide range of best practices, project evaluations, lessons learned, case studies, methodological notes, and other documents of a technical nature. The information and opinions presented in these publications are entirely those of the author(s), and no endorsement by the Inter-American Development Bank, its Board of Executive Directors, or the countries they represent is expressed or implied.
This paper would not have been possible without the motivation and collaboration of the researchers participating in this project: Diego Aboal, Roberto Álvarez, Claudio Bravo-Ortega, Gabriela Dutrénit, Claudia De Fuentes, Juan Gallego, Paula Garda, Natalia Gras, Luis Gutierrez, Fernando Santiago, Rodrigo Taborda, Mario Tello, Arturo Torres, and Andrés Zahler. However, the authors are solely responsible for any errors and omission in this paper.

## 1. Introduction

Although per capita GDP in most Latin American and Caribbean (LAC) countries has been rapidly rising over the last decade, it still lags significantly behind that of developed countries. Moreover, productivity, the main driver of long-term economic growth, has been rising at a slower rate than the world technological frontier growth rate (IDB, 2010). Thus, increasing productivity is the main challenge for LAC countries. The performance of the service industry plays a key role in this regard.

While the contribution of the service sector to the economies of LAC countries has been increasing, its productivity has remained persistently low (IDB, 2010). This poor performance impacts the economy as a whole in many ways. First, traditional services, such as transportation, logistics, and wholesale trade, are the links connecting the different stages of production in the whole economy. Thus, low productivity in these subsectors directly affects the productivity of goods production. Second, knowledge-intensive business services (KIBS), such as research and development (R&D), engineering, and information technology, can strengthen the innovative capacity of economies, expanding long-term growth potential (Europe Innova, 2011; Sissons, 2011; OECD, 2001). Finally, services and manufacturing are increasingly becoming integrated activities within firms. This is particularly true of manufacturing firms that are introducing new or improved services to the market (Santamaría et al., 2012).

Evidence from industrialized countries suggests that investing in innovation activities leads to productivity growth (OECD, 2009; Hall, 2011). This relationship holds for manufacturing firms in LAC countries (Crespi and Zúñiga, 2010). However, little attention has been paid to what is happening in terms of innovation and productivity in the service sector. Usually considered “innovation averse” or less innovative (Baumol, 1967; Pavitt, 1984), services are increasingly being seen as key inputs and outputs of the innovation process (Kuusisto, 2008) and, particularly in the case of KIBS, as co-producers of innovations (Hertog, 2000). Evidence from OECD countries suggests that service firms innovate for the same reasons that manufacturing firms do (OECD, 2005), but the well-known correlation between firm size and likelihood of innovation is weaker in services. Despite the interest in developed economies in improving understanding and promoting innovation in the service industry (Cainelli et al., 2006; Europe Innova, 2011; Gallouj and Savona, 2008; Kuusisto, 2008; OECD, 2005, 2009a, b, 2010; Rubalcaba and Gago, 2006; Uppenberg and Strauss, 2010), evidence on this subject in LAC is scarce (Tacsir, 2011).

The purpose of this study is to provide new evidence on the determinants of innovation and their impact on productivity for service firms through the standardization and comparison of a series of empirical studies in three LAC countries—Chile, Colombia, and Uruguay—using data from national innovation surveys. Although some aspects of the questionnaires and the sample design of the innovation surveys vary among countries, the empirical strategy enables their results to be compared. The empirical strategy of these studies is based on the seminal work of Crépon, Duguet, and Mairesse (1998), which models the relationship between innovation and productivity through the following recursive structure: i) firm decision to engage in innovation and activities and intensity of investment, ii) knowledge production function (or how much knowledge is created) as a result of innovation efforts, and iii) impact of the knowledge created on firm productivity.

The paper is organized as follows. Section 2 presents an overview of the relevant literature on the determinants of innovation and productivity in service firms. Section 3 describes the model, data, and empirical strategy used. Section 4 presents the results of the three equations of the model, comparing manufacturing and services among countries, and Section 5 concludes.

## 2. Literature Review

During the last decades both developed and developing countries have been moving towards more service-oriented economies. Services accounted for 50% of the valued added of the world in 1970, and this figure went up to 66% nowadays (Rubalcaba, 2013). In Latin American countries this change also reflects in the fact that services has been increasing in share of employment, going up from 40% of the labour force in 1970, to the 60% in 2005 (Crespi, 2013). The Inter-American Development Bank (IDB) (2010) has stated that enhancing productivity in services is one of the key challenges of the region, in order to increase aggregate productivity. Besides the impact of increments in the productivity of the sector itself, service subsectors, such as transportation, logistics, and wholesale trade, are the links connecting the different activities of the whole economy. Thus, increasing the productivity of services directly affects the performance of other industries. Furthermore, KIBS are a source of knowledge for the whole economy and are often co-producers of innovation with firms from other sectors (Hertog, 2010).

The study of innovation and productivity in services is still relatively new. Empirical evidence on the determinants of innovation and its impact on productivity growth in service firms, although increasing (Cainelli et al., 2006; ; Europe Innova, 2011; Gallouj and Savona, 2008; Kuusisto, 2008; OECD, 2009a, b, Rubalcaba and Gago, 2006; Uppenberg and Strauss, 2010), is scarce. This lack of research is particularly striking in LAC countries, where there has been no systematic study of innovation in services (Tacsir, 2011).

The service industry has characteristics that differentiate it from the manufacturing sector. For example, services are intangible, non-durable, and non-storable. Production and consumption often occur simultaneously, and it is difficult to separate the service from the service provider. Furthermore, there is substantial heterogeneity among service firms and subsectors, mainly driven by the limited alternatives to standardized production and distribution (Menon-Econ, 2006). In addition, as Tether (2005) notes, the production of services is often tailor-made, making extremely difficult to differentiate between service variation and service innovation.

There are three main research approaches to the study of innovation in services (Mothe and Nguyen-Thi, 2010). The *assimilation approach* considers that the drivers and the results of innovation in service firms are not substantially different from those in manufacturing firms; therefore, theories and conceptual frameworks based on R&D and technological innovation adequately model the behaviour of service firms. The *demarcation approach* considers that the characteristics of services, such as those mentioned above, limit the capacity to define and measure product quality and firm productivity in the same way as in other industries; hence, specific frameworks must be developed to understand this industry. The third perspective, the *synthesis approach*, acknowledges the differences between innovation in services and in manufacturing but maintains an integrative approach that incorporates characteristics of both sectors (Gallouj and Weinstein, 1997).

This study is framed within the latter approach. Even though the econometric model used by all of the country studies analysed here was originally developed to understand the relationships between R&D investments and their impacts on productivity in manufacturing firms, the empirical strategies implemented enable an exploration of the dissimilarities between services and manufacturing.

Quantitative evidence on service innovation has emerged mainly from research using data from innovation surveys in industrialized countries, specifically, the Community Innovation Survey (CIS), which has been administered in the service sectors in Norway, Iceland, and the countries of the European Union since its second wave in 1996. Using this dataset from Italy, Sirilli and Evangelista (1998) have shown that the service industry is much more heterogeneous than manufacturing with regard to innovation activities. Moreover, some service subsectors have levels of innovation activity similar to those of manufacturing firms (Bogliacino, Lucchese, and Pianta, 2007; Evangelista and Savona, 2003). However, those same studies show that the types of innovation investments differ greatly between service and manufacturing firms. In services, innovation is a consequence of incremental processes that do not necessarily rely on formal R&D. Nonetheless, Leiponen (2012), studying innovation determinants in Finnish firms, finds that R&D still plays a significant role in introducing service innovations.

With regard to the impact of innovation on productivity, Cainielli et al. (2006) analyse innovation and productivity of Italian firms and find a strong relationship between past performance, innovation, and productivity. The study emphasizes the importance of investment in information and communication technologies (ICT) on productivity growth in service firms. Along these same lines, Gago and Rubalcaba (2007) highlight the role of adoption of ICT by service firms as a driver of innovation, more frequently organizational innovation, facilitating the two-way interaction between service providers and users. Loof and Hesmati (2006), implementing the CDM model using CIS data from Sweden, find that the relationships between innovations input and innovation output and between innovation output and productivity were remarkably similar in services and in manufacturing. A cross-country comparative study by the OECD (2009) concludes that the process of innovation is more "open" in services than in manufacturing, relying to a greater extent on external sources of knowledge and collaboration with other institutions, and that the impact of product innovation on labour productivity is consistently higher in manufacturing than in services.

# 3. Model and Data

## 3.1 The Model

In the studies presented in this paper, the relationship between innovation inputs and outputs and productivity is estimated through an econometric model based on the system of equations developed by Crépon et al. (1998), also called the CDM model. This model is structured by four equations as follows: (i) firm decides to engage in innovation activities, (ii) firm decides the intensity of the investment in innovation activities (in terms of innovation expenditures per worker), (iii) the knowledge or innovation production function (output) as a consequence of the innovation investments (inputs), and (iv) the impact on product or productivity of the knowledge produced along with other inputs. In addition to characteristics of the firm, the model incorporates external forces and framework conditions of markets that could shape firm innovation behaviour, namely, spillovers, demand pull (regulation) and technological push (scientific opportunities) indicators, and public policies (i.e., incentives or subsidies for innovation or R&D).

The CDM model addresses selection bias and endogeneity problems that generally affect studies of innovation and productivity at the firm level. The first problem arises from the fact that it is only possible to observe innovation expenditure in those firms that claim to be investing in innovation. Since Heckham (1979), it is well known that studying the determinants of innovation expenditure using only this subset of firms may lead to sample selection bias in the estimated parameters of interest. The bias is corrected by taking into account the decision by firms to engage in innovation activities (selection equation). In addition, the multiple-stage estimation strategy of the CDM model deals with simultaneity by considering innovation expenditure to be endogenous to the innovation production equation, and innovation output to be endogenous to the production equation.

The first two equations of the model account for the innovation behaviour of the firm, that is, the decision to invest in innovation and the intensity of investment. Then, the innovative effort $IE_i^*$ is an unobservable latent variable for the firm $i$:

$$IE_i^* = z'_i\beta + e_i \; (1)$$

where $z_i$ is a vector of determinants of innovation effort, $\beta$ is a vector of parameters of interest, and $e_i$ an error term. The selection equation, describing the decision of the firm $i$ to engage in innovation activities or not ($ID_i$) follows

$$ID_i = \begin{cases} 1 \; if \; ID_i^* = w'_i\alpha + \varepsilon_i > c, \\ 0 \; if \; ID_i^* = w'_i\alpha + \varepsilon_i \leq c, \end{cases} (2)$$

where $ID_i^*$ is an unobservable latent variable that expresses the firm criterion to invest in innovation activities if it is above a threshold level $c$. $w_i$ is a vector of explanatory variables, $\alpha$ the associated vector of parameters and $\varepsilon_i$, the error term. Thus, conditional on a firm deciding to invest in innovation ($ID_i$=1), we observe the intensity of the investment ($IE_i$) as

$$IE_i = \begin{cases} IE_i^* = z'_i\beta + \varepsilon_i \; if \; ID_i = 1, \\ \quad 0 \qquad\qquad if \; ID_i = 0 \end{cases} (3)$$

Under the assumption that error terms from equations (1) and (2) are bivariate normal with mean zero, variances $\sigma_\varepsilon^2 = 1$ and $\sigma_e^2$, and correlation $\rho_{\varepsilon e}$, equations (2) and (3) could be estimated as a generalized Tobit model by maximum likelihood. The production of innovations equation follows

$$TI_i = IE_i^*\gamma + x'_i\delta + u_i, \; (4)$$

where $TI_i$ is a binary variable indicating if firm $i$ introduced technological innovation (product or process), and is explicated by the latent innovation effort and a vector of other explanatory variables, $x$. $\gamma$ and $\delta$ are the related coefficients, and $u$, the error term. Finally, the output equation is modelled assuming a Cobb-Douglas technology, with innovation, capital, and labour as inputs

$$Y_i = \pi_1 k_i + \pi_2 TI_i + v_i \text{ (5)}$$

where $Y_i$, the output per worker of the firm $i$, is a function of the physical capital per worker of the firm $i$, $k_i$, and the introduction of technological innovation (TI). $\pi_1$ and $\pi_2$ are the parameters of interest and $v$, the error term.

The empirical strategy undertaken in the studies analysed in this paper is based on the specification of the CDM model developed by Crespi and Zúñiga (2010). The authors studied innovation and productivity in the manufacturing industry in six LAC countries, adapting the CDM model to address specificities of Latin American firms and economies using data from national innovation surveys. First, the definition of innovation activities is much broader than the one typically used in industrialized economies. In this study, all those actions taken by a firm for the purpose of incorporating or assimilating new knowledge are considered innovation activities. Besides R&D investments, they also include the purchase of machinery, the acquisition of hardware and software, engineering and industrial design activities, disembodied technology purchases, training, and marketing activities. Second, as distinct from the traditional measurement of output of the knowledge equation using the number of patents granted, this specification uses a dichotomous variable, self-reported by the firm, indicating whether the firm has successfully introduced a technological innovation (a new or significantly improved product or process) to the market. Although the definition of product and process innovation is common among innovation surveys in LAC countries, the use of this variable could be introducing measurement errors to the model, since the interpretation of what each firm considers to be an innovation may vary from firm to firm. However, since patenting, a less subjective instrument to measure innovation outputs, is very unusual among Latin American firms, the low variability of this variable renders this specification not very useful. Third, although the knowledge production equation requires measurement of stock of knowledge (knowledge capital) per worker as an input, innovation surveys in LAC are cross-sectional, designed only to account for knowledge investments in the previous period through recall data. Lastly, rather than estimating product and process innovation separately, the strategy adopted focuses on the measurement of technological innovation, that is, firms that innovate in products or processes. The reason is that innovative firms in LAC often innovate jointly in products and processes, giving rise to identification problems in the estimation of equation (4), and making it very difficult to estimate these two effects separately.

### 3.2 Data, Empirical Implementation, and Indicators

The econometric results presented in this paper come from country studies conducted in Chile, Colombia, and Uruguay, where the same CDM model specification was applied to manufacturing and service industries.[1] Additionally, some innovation indicators and statistics were extracted from two other similar country studies, of Mexico and Peru.[2] All of these country studies used data from national innovation surveys implemented in the aforementioned countries between 2005 and 2010. While in Chile, Mexico, Peru, and Uruguay the innovation survey is conducted simultaneously in manufacturing and services, in Colombia, these industries are surveyed in two different waves (using the same questionnaire) in consecutive years. Another particularity of the Colombian innovation survey is that while all manufacturing firms in the country above a certain size threshold are surveyed, the service sector is covered through a representative sample of firms. The rest of the countries use a representative sampling methodology for both services and manufacturing.

There are some other design aspects where these surveys differ from each other that should be borne in mind when interpreting and comparing indicators and results. The reference period for the innovation surveys conducted in these countries is not the same. In Uruguay, the reference period is three years, while in Chile, Colombia, and Mexico it

[1] Additionally, KIBS and traditional services are estimated separately, but these econometric results are not analysed in this paper.

[2] The econometric specifications implemented in these studies, although similar, are different enough not to allow a direct comparison.

is two years, and in Peru it is just one year.[3] According to Álvarez et al. (2010), there is a lagged effect of innovation on productivity in Chilean manufacturing firms. This may imply that impacts would be more difficult to observe in country surveys with shorter reference periods. At the same time, those surveys that cover longer time spans may show higher innovation rates than in shorter reference period surveys.

The minimum firm size in the sample design also varies from one country to another. In Colombia, Mexico, and Uruguay, firm size is defined by number of employees, but the threshold considered is different. In Uruguay, firms with five or more employees are surveyed. Ten employees is the minimum size of firms included in the Colombian Innovation Survey, and 20 employees is the threshold for firms surveyed in Mexico. In Peru, minimum firm size is determined by annual turnover, defining the target population as all firms with \$35,000 (approximately[4]) or more of annual turnover. In the case of Chile, the statistical population comprises service firms with 10 or more employees, and manufacturing firms with at least \$100,000 (approximately[5]) of annual turnover and simultaneously employing 10 or more workers.

Firm size has been found to be a strong predictor of participation in innovation activities (Benavente, 2006; Crespi and Peirano, 2007). Larger firms have sufficient scale and access to needed resources to engage in innovation activities with less difficulty than small and medium-sized enterprises (SMEs). Therefore, surveys using samples with larger minimum firm size are removing smaller and more restricted firms from the analysis, thus reducing the variance of this variable and making it more difficult to observe the firm size effect in the selection equation (1).

Finally, there is heterogeneity in the coverage of the service industry in the surveys used. Although all of these countries place special emphasis on surveying KIBS firms, the traditional service subsectors included in the samples vary among country surveys. As Sirilli and Evangelista (1998) show, there is a high degree of heterogeneity in innovation behaviour among service subsectors. Therefore, to exclude (or include) any

[3] In the last wave of the Peruvian innovation survey (2012), the reference period was changed to three years.
[4] Equivalent to \$100,000 Peruvian Nuevo Soles.
[5] Equivalent to 24,000 UF.

particular subsector increases the complexity of comparing estimation results from different countries.

Two waves of innovation surveys were used for Chile (2007 and 2009) and Uruguay (2007 and 2010), using a pooled data approach. Only one wave of innovation surveys was used in the Colombia (manufacturing, 2009; and services, 2010), Mexico (2010) and Peru (2005) studies. The main characteristics of the innovation surveys used and the sectors included in this study are presented in Table 1.

**Table 1: Innovation Surveys**

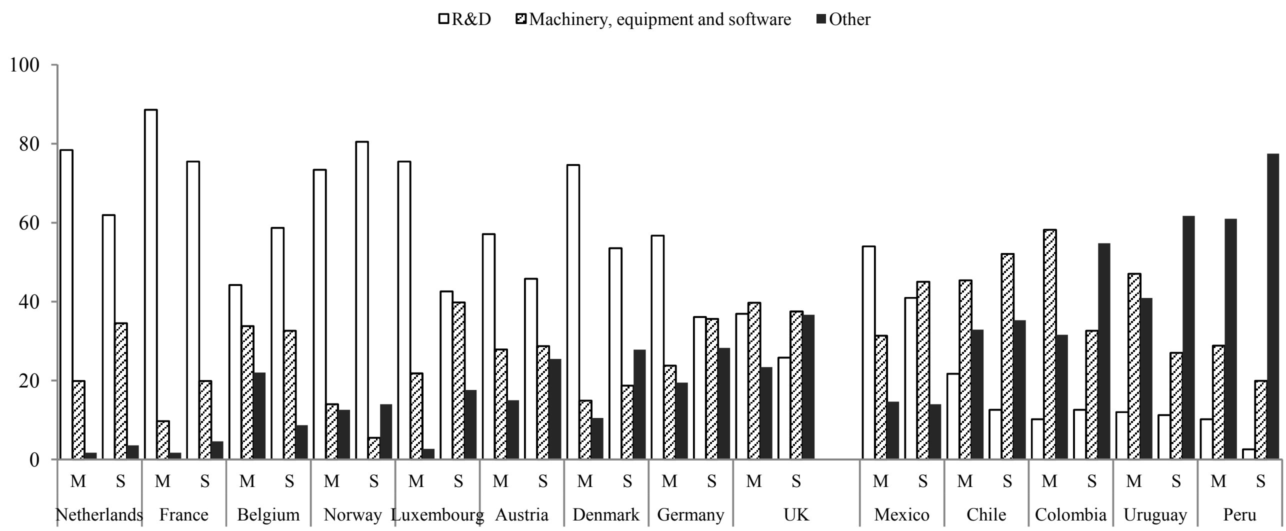
| | Chile | Colombia | Mexico | Peru | Uruguay |
|---|---|---|---|---|---|
| Innovation survey | EIE | EDIT[d] | ESIDET | ENCYT | AEAI[e] |
| Wave[a] | 2007-2009 | 2009-2010 | 2010 | 2005 | 2007-2010 |
| Reference period | 2 years | 2 years | 2 years | 1 year | 3 years |
| Source | INE | DANE | INEGI | CONCYTEC | INE |
| Economic activities[b] | | | | | |
| Services | | | | | |
| Traditional Services | E, F, G, H, J, N, O | E(40), G, H, I(60), O(90) | 43, 48-49, 51, 52, 531, 56,71, 72, 81 | E, G, H, K(71), N, O | E(40), H, I, K(71), N |
| KIBS | I, K | E(41), I(62, 64), J(65), K(72), O(92) | 533, 54, 55 | I, J, K(72, 73, 74) | K(72, 73, 74) |
| Manufacturing | D | D | 31-33 | D | D |
| Sample size | 7192 | 8830 | 4156 | 3888 | 3595 |
| Minimum firm size | \$100,000 Turnover[c] | 10 employees | 50 employees | \$35,000 Turnover | 5 employees |

[a] Year of implementation.
[b] ISIC rev. 3.1 for Chile, Colombia, Peru, and Uruguay. NAICS for Mexico.
[c] For manufacturing firms, having 10 or more employees is also required.
[d] Data from this survey are matched with data from the Annual Economic Survey for the service sector (EAS) and the Annual Economic Survey for the manufacturing sector (EAM).
[e] Data from this survey are matched with data from the Economic Activity Survey (EAS).

With regard to differences in innovative behaviour between service and manufacturing firms, one of the more remarkable findings is the contrast in the composition of the innovation inputs matrix, specifically, that services rely more on non-R&D investments than manufacturing (Tether and Massini, 2007). Figure 1 shows that firms in LAC countries, regardless of the economic activity, are notably less intensive in R&D activities than firms in industrialized countries. The difference between manufacturing and services in LAC countries is that while manufacturing firms invest, on average, more intensively in machinery acquisition, service firms base their innovation inputs on other activities, namely, engineering and industrial design, disembodied technology, training, and marketing.

**Figure 1: Distribution of Innovation Expenditure**

*(percent of total innovation expenditure)*




Note: Authors' elaboration with data from Aboal and Garda (2012) , Álvarez et al. (2012), Dutrénit et al. (2013), Gallego et al. (2013), Tello (2013), and OECD (2009).
M: Manufacturing; S: Services.

Table 2 shows that among service subsectors, with the notable exception of Mexico, KIBS firms tend to allocate significantly more of their innovation investment budget in R&D than firms from other service sectors.

**Table 2: Distribution of Innovation Expenditure**

*(percent of total innovation expenditure)*

| | R&D (Internal and external) | | Machinery, equipment and software | | Other | |
|---|---|---|---|---|---|---|
| Country | KIBS | Traditional Services | KIBS | Traditional Services | KIBS | Traditional Services |
| Colombia | 20.3 | 9.3 | 35.5 | 35.6 | 44.2 | 55.1 |
| Uruguay | 17.9 | 7.4 | 10.5 | 36.6 | 71.6 | 56.0 |
| Chile | 17.0 | 9.7 | 47.9 | 54.9 | 35.1 | 35.4 |
| Mexico | 16.1 | 30.7 | 55.9 | 40.6 | 28.0 | 28.7 |
| Peru | 3.3 | 2.2 | 16.9 | 21.2 | 79.8 | 76.5 |

Note: Authors' elaboration with data from Aboal and Garda (2012), Álvarez et al. (2012), Dutrénit et al. (2013), Gallego et al. (2013), and Tello (2013).

Regarding innovation output, Figure 2 shows that technological innovation is consistently more frequent in manufacturing than in services in OECD countries, a pattern that holds for LAC countries. On the other hand, non-technological innovation rates are very similar between manufacturing and services in industrialized countries and within the sample of LAC countries analysed in this study. Observed innovation rates in both services and manufacturing in LAC countries lag behind the average of this sample of industrialized countries.

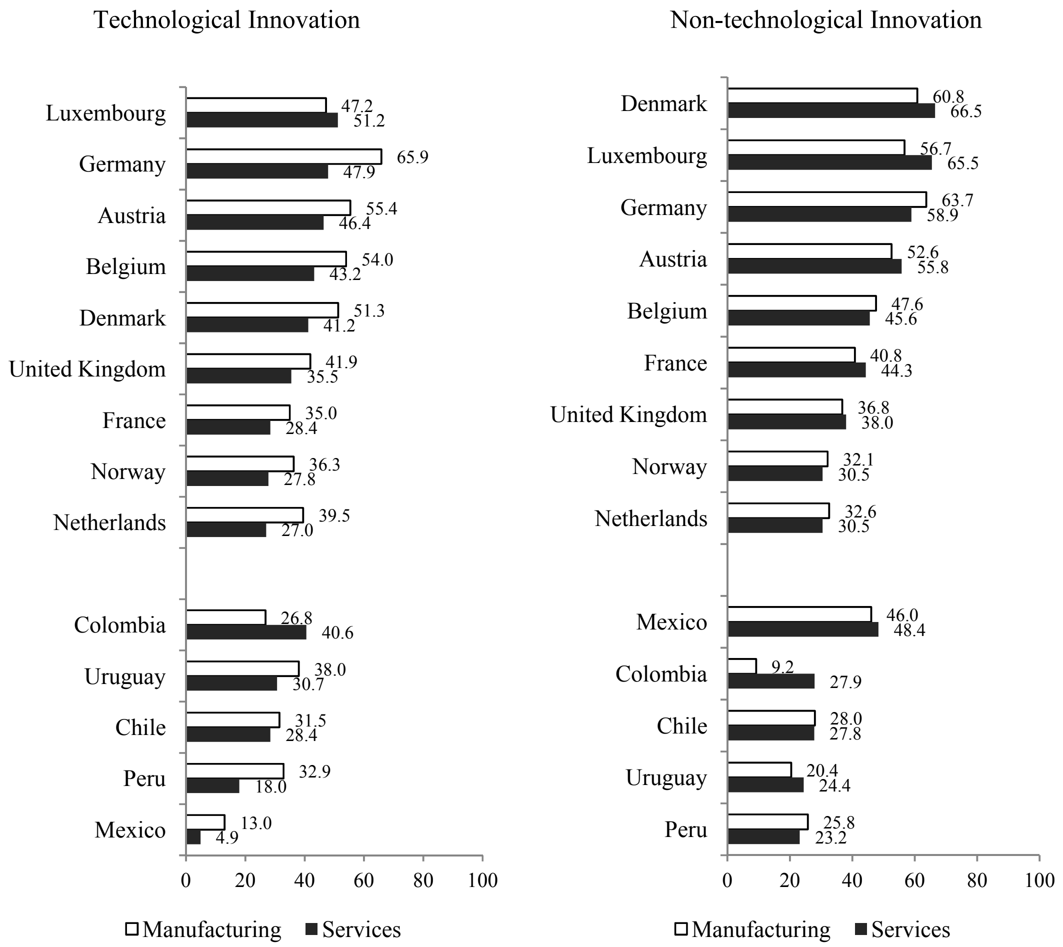
With respect to service subsectors, Table 3 shows that KIBS firms are consistently more innovative than firms operating in traditional services, in terms of both technological and non-technological innovation.

**Table 3: Share of Innovating Firms**

| | Technological innovation | | Non-technological innovation | |
|---|---|---|---|---|
| Country | KIBS | Traditional services | KIBS | Traditional services |
| Colombia | 48.0 | 34.6 | 32.1 | 25.2 |
| Uruguay | 33.8 | 29.1 | 27.4 | 22.8 |
| Chile | 30.4 | 27.2 | 28.8 | 27.2 |
| Peru | 23.0 | 16.1 | 23.4 | 23.1 |
| Mexico | 15.3 | 2.5 | 60.7 | 45.4 |

Note: Authors' elaboration with data from Aboal and Garda (2012) Álvarez et al. (2012), Dutrénit et al. (2013), Gallego et al. (2013), and Tello (2013).

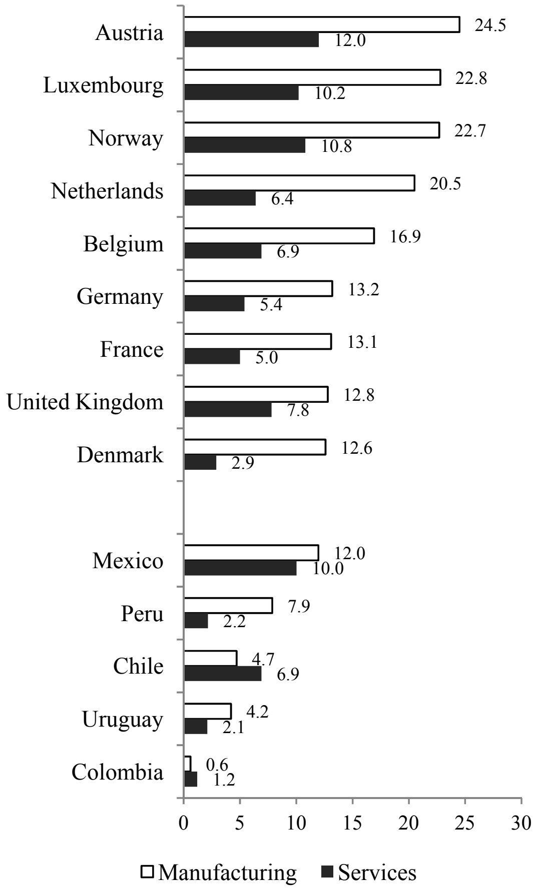
**Figure 2: Share of Innovating Firms**




Note: Authors' elaboration with data from Aboal and Garda (2012), Álvarez et al. (2012), Dutrénit et al. (2013), Gallego et al. (2013), Tello (2013), and OECD (2009).

Although service firms are as innovative as manufacturing firms, the fact that the more important inputs to innovation are activities that are somewhat different from the traditional view of technological innovation may be causing a bias toward (against) manufacturing (service) firms in the allocation of public resources to support innovation. Figure 3 shows that in industrialized and LAC countries, with the exception of Chile, a larger share of manufacturing firms receives public funds to support innovation activities than service firms. Within the latter, KIBS firms are much more likely to receive financial support from public sources than firms operating in traditional services.

## Figure 3: Share of Firms that Received Public Financial Support for Innovation




Note: Authors' elaboration with data from Aboal and Garda (2012), Álvarez et al. (2012), Dutrénit et al. (2013), Gallego et al. (2013), Tello (2013), and OECD (2009).

## Table 4: Share of Firms that Received Public Financial Support for Innovation

| Country | Public Support KIBS | Public Support Traditional Services |
|---|---|---|
| Mexico | 30.0 | 5.1 |
| Colombia | 8.7 | 0.7 |
| Chile | 8.1 | 6.0 |
| Peru | 3.1 | 1.8 |
| Uruguay | 1.9 | 2.3 |

Note: Author's elaboration with data from Aboal and Garda (2012), Álvarez et al. (2012), Dutrénit et al. (2013), Gallego et al. (2013), and Tello (2013).

The econometric specification of the studies analysed here closely follows the work of Crespi and Zúñiga (2010), although some dissimilarity arises, mainly due to differences in the variables covered in the country innovation surveys. There is strong evidence supporting the importance of firm size (*EM*) in predicting a firm's decision to engage in innovation (Benavente, 2006; Cohen and Levinthal, 1989; Crespi and Peirano, 2007; OECD, 2009). Larger firms have more resources and greater output, which allows them to absorb fixed costs associated with innovation investments. As Crespi and Zúñiga (2010) point out, larger firm size is not necessarily associated with higher investment in innovation; thus, firm size is not included in the intensity of investment equation (this variable is already scaled down in per capita terms).

Exporting activities (*EX*) and firm ownership (*FO*) are also included in the vector of explanatory variables. Firms that operate in foreign markets are more likely to be exposed to higher standards and levels of competition, fostering a need to innovate. OECD (2009) reports evidence in this direction for manufacturing firms in several developed economies, as do Alvarado (2000) in Colombia, De Negri et al. (2007) in Brazil, and Zúñiga et al. (2007) in Mexico. The relationship between foreign direct investment and innovation is less clear. Subsidiaries of multinationals companies may be more prone to innovate due to their access to superior technology and human capital from headquarters located in more industrialized countries, and to having fewer financial constraints than their same-size local counterparts. On the other hand, business models of multinationals companies may opt to concentrate R&D and innovation efforts in their home-country locations, working with subsidiaries on less innovative activities (Navarro et al., 2010). Crespi and Zúñiga (2010) find that while foreign ownership increases the likelihood of engaging in innovation activities for manufacturing firms in Argentina, Panama, and Uruguay, there is no statistical correlation between the two in Chile, Colombia, or Costa Rica. The authors argue that the innovation strategy implemented by multinationals in their subsidiaries is also affected by characteristics of the markets where they are operating. The market size, degree of competition, and technological sophistication they face influence the strategy of the multinationals and their subsidiaries.

A variable measuring patent activities (*PA*) is also included. This parameter indicates whether a firm has filed patents in the past or in the current period (Chile and

Uruguay) or whether it has obtained a patent in the period (Colombia). This variable serves as an indicator of firm skills and knowledge. First, filing or obtaining a patent suggest that the firm has enough managerial skills to start and/or successfully complete the complex process of patent application. Second, it is an indicator of the stock of knowledge that each firm possesses in the current or previous period. In Colombia, the authors added an extra variable indicating whether a firm has an R&D department as another way to control for stock of knowledge and research management skills.

Innovation and R&D investments are difficult to finance, mainly due to the high risk and the inherent uncertainty of these activities. Thus, lack of access to financing is one the most important obstacles to innovation in LAC countries (Navarro et al., 2010). Access to public financial support (*FIN*) is included in the selection and intensity equation because the ability to access additional resources could determine whether or not a firm decides to engage in innovation, and in the intensity equation because these resources could increase the investment of a firm's own resources. Hall and Maffioli (2008) and Mairesse and Mohnen (2010) show that there is no evidence of crowding out by public financial support to R&D.

Additional variables are included in the intensity of investment equation, starting with cooperation (CO) for innovation with other institutions (including firms, universities, among others). This variable was also included in the selection equation in the Uruguayan study, arguing that, in addition to any complexity in the redistribution of returns on the investment, joint innovation enables the cost of innovation activities to be spread, thus relaxing financial constraints.

A set of variables indicating the importance of different sources of information is also included. These variables are typically divided into three aspects: market (*INFO1*), scientific (*INFO2*), and public sources (*INFO3*) of information. While in the Chile study these variables are an index between 0 and 100 percent (100% meaning maximum importance), Colombia and Uruguay present a set of dummies indicating whether the firm considers any of these sources of information to be important.

Finally, the productivity function is estimated using the predicted value of technological innovation, firm size, a measure of capital per employee (where available), and non-technological innovation as explanatory variables.

## Results

### 3.3 Decision to Invest

The results of the first-stage estimations for the manufacturing and service industries in each country are presented in Table 5. Estimation results of the selection equation are presented in the upper section of the table. The lower part of the table shows the results of the investment intensity equation. Consistent with previous findings, these results show that larger firm size (*EM*) increases the probability that a firm will invest in innovation. In all of the countries studied, size is significantly less relevant in predicting engagement in innovation activities in service firms than in manufacturing firms, suggesting that the need for infrastructure and associated sunk costs are lower in services.

No consistent relationship is found between foreign ownership of the firm (FO) and the decision to invest in innovation. Although marginal effects are mostly positive, their relative importance for manufacturing and services varies from country to country. Moreover, with the exception of Colombian manufacturing firms, FO is not statistically significant in this equation. Regarding intensity of investment, foreign-owned firms invest more heavily in Colombia than their local counterparts. The same situation is observed in the case of the Uruguayan service industry. No statistical effect is found in Chile. These results are somewhat in line with the variability of the effect of foreign ownership reported by Crespi and Zúñiga (2010).

Service firms that export (EX) are more likely to invest in innovation than non-exporting service firms. In the case of Chile, the importance of this effect is comparable to that observed in manufacturing firms, but in Uruguay, the effect of exporting activities is remarkably higher in services than in manufacturing. Furthermore, exporting firms invest more intensively in Chile, both in services and manufacturing, but no statistical effect is found in Uruguay. The Colombian study does not allow a comparison to be made between manufacturing and service exporting firms, because this variable is not available for the latter.

The patent protection variable (PA) has a positive and strong effect, increasing the probability of engaging in innovation activities in Chile and Uruguay in both service and manufacturing industries.[6] Although this effect is similar among these sectors, patent protection only increases the intensity of investment in innovation in the service sector. These results suggest that formally protecting knowledge and/or having adequate capacity to managing knowledge increases the likelihood that firms will continue their involvement in innovation activities. Access to public financial support (FIN) for innovation activities increases the intensity of innovation investment consistently across countries. The effect is higher in services than in manufacturing, but only statistically significant in Chile and Colombia. FIN was also included in the Uruguay study as a variable explaining the decision to invest. The use of public financial support was found to increase the probability of engaging in innovation in the service and manufacturing industries.

Cooperation in innovation increases the intensity of innovation investment in the countries studied. These results are in line with previous findings from LAC (Crespi and Zúñiga, 2010) and from industrialized countries (OECD, 2009; Veugelers and Cassiman, 1999). The effect is remarkably higher in the service sector than in the manufacturing sector. In the Uruguay study, the cooperation variable was also added to the selection equation. The effect was found to be positive and statistically significant for both manufacturing and services.

Additionally, the Colombian study includes a variable in the selection equation controlling for the existence of an R&D department and, as expected, it has a positive and significant effect accounting for the path dependence in innovation activities.

Finally, no consistent results could be extracted from the analysis of the sources of information on the intensity of investment equation. Neither market (*INFO1*) nor scientific (*INFO2*) sources of information are associated with higher innovation investments in the service sector. Public sources of information (*INFO3*) show complementarities with innovation efforts only in the Uruguayan service sector.

[6] Patent protection information was not available for service firms in Colombia.

## Table 5: Probability of Investing in Innovation Activities and Intensity of Innovation Investment per Employee

| | Chile | | Colombia | | Uruguay | |
|---|---|---|---|---|---|---|
| | Services | Manufacturing | Services | Manufacturing | Services | Manufacturing |
| ID (probability of investing in innovation) | | | | | | |
| EX | 0.065** | 0.079*** | n.a. | -0.066* | 0.375*** | 0.071 |
| | (0.029) | (0.023) | | (0.039) | (0.086) | (0.064) |
| FO | 0.014 | 0.023 | 0.254 | -0.224*** | 0.141 | 0.092 |
| | (0.024) | (0.031) | (0.259) | (0.061) | (0.126) | (0.131) |
| EM | 0.055*** | 0.097*** | 0.289*** | 0.418*** | 0.248*** | 0.372*** |
| | (0.003) | (0.007) | (0.039) | (0.012) | (0.022) | (0.025) |
| PA | 0.307*** | 0.359*** | n.a. | 0.489*** | 1.491*** | 1.884*** |
| | (0.053) | (0.053) | | (0.117) | (0.329) | (0.525) |
| FIN | … | … | … | … | 1.984*** | 2.182*** |
| | | | | | (0.413) | (0.506) |
| R&D | … | … | 0.401** | 0.565*** | … | … |
| | | | (0.165) | (0.050) | | |
| CO | … | … | … | … | 1.282*** | 1.525*** |
| | | | | | (0.175) | (0.207) |
| C | … | … | … | … | -1.789*** | -2.109*** |
| | | | | | (0.063) | (0.129) |
| INFO | No | No | No | No | Yes | Yes |
| IE (log innovation expenditure per employee) | | | | | | |
| EX | 0.425** | 0.645*** | n.a. | 0.524*** | 0.518 | 0.159 |
| | (0.200) | (0.157) | | (0.094) | (0.323) | (0.106) |
| FO | 0.098 | 0.318 | 1.330*** | 1.123*** | 0.570** | 0.030 |
| | (0.233) | (0.194) | (0.367) | (0.141) | (0.224) | (0.139) |
| PA | 0.662*** | 0.258 | n.a. | -0.244 | 0.503** | -0.383 |
| | (0.237) | (0.224) | | (0.250) | (0.245) | (0.349) |
| CO | 0.677*** | 0.533*** | 0.620*** | 0.278*** | 1.001*** | 0.525*** |
| | (0.124) | (0.139) | (0.200) | (0.075) | (0.337) | (0.165) |
| FIN | 0.472** | 0.276 | 1.916*** | 0.503** | 0.994 | 0.649*** |
| | (0.225) | (0.218) | (0.720) | (0.226) | (0.660) | (0.247) |
| INFO1 | 0.151 | -0.065 | 0.339 | 0.324*** | 0.367 | 0.291 |
| | (0.172) | (0.174) | (0.244) | (0.078) | (0.299) | (0.203) |
| INFO2 | -0.120 | -0.001 | 0.288 | 0.059 | 0.041 | -0.019 |
| | (0.101) | (0.102) | (0.236) | (0.084) | (0.173) | (0.207) |
| INFO3 | 0.007 | 0.008 | 0.376 | 0.002 | 0.356*** | 0.085 |
| | (0.128) | (0.148) | (0.244) | (0.078) | (0.065) | (0.112) |
| C | … | … | … | … | -0.064 | 2.219** |
| | | | | | (0.565) | (0.336) |
| ISIC | No | No | No | No | Yes | Yes |
| Observations | 4,023 | 2,682 | 562 | 7,203 | 1,868 | 1,727 |

Source: Authors elaboration with data from Aboal and Garda (2012), Álvarez et al. (2012), and Gallego et al. (2013).
Notes: Coefficients reported are marginal effects.
Standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1

### 3.4 Impacts of Investment on Innovation

Table 6 presents the results of the estimation of the innovation production function equation. The first finding is that the intensity of innovation investment is consistently positive and significant for services and manufacturing in all countries. It is interesting to note that the importance of the investment is lower for service than for manufacturing firms, in line with the argument suggesting that innovation in services relies more on informal activities than does innovation in manufacturing.

Larger firms are more likely to introduce technological innovations in the service sectors of Chile and Uruguay, but they are less important than in manufacturing. In Colombia, this difference is even more pronounced. While firm size is a highly important determinant of innovation in manufacturing, it is not statistically significant in services.

Exporting (EX) shows a negative effect in manufacturing and services regarding technological innovation, but it is not statistically significant in the Uruguayan service sector. Foreign-owned firms (FO) present a similar pattern, showing consistently significant negative effects in both industries. These results should be considered with caution. The characteristics of local and destination markets could be influencing these findings, suggesting that a sharper definition is needed to understand this phenomenon.

**Table 6: Probability of Technological Innovation**

| | Chile | | Colombia | | Uruguay | |
|---|---|---|---|---|---|---|
| | Services | Manufacturing | Services | Manufacturing | Services | Manufacturing |
| Technological Innovation | | | | | | |
| IE_p | 0.494*** | 0.603*** | 0.780*** | 2.489*** | 1.387*** | 2.332*** |
| | (0.047) | (0.057) | (0.104) | (0.070) | (0.293) | (0.333) |
| EM | 0.035*** | 0.075*** | 0.077 | 0.224*** | 0.196*** | 0.346*** |
| | (0.004) | (0.008) | (0.047) | (0.017) | (0.026) | (0.032) |
| EX | -0.247*** | -0.391*** | n.a. | -1.319*** | -0.363 | -0.253** |
| | (0.021) | (0.035) | | (0.058) | (0.230) | (0.099) |
| FO | -0.076*** | -0.204*** | -0.722*** | -2.845*** | -0.878*** | -0.116 |
| | (0.024) | (0.026) | (0.276) | (0.103) | (0.216) | (0.131) |
| CO | … | … | … | … | -0.142 | 0.183 |
| | | | | | (0.302) | (0.230) |
| C | … | … | … | … | -1.682*** | -7.578*** |
| | | | | | (0.145) | (0.753) |
| INFO | No | No | No | No | Yes | Yes |
| ISIC | No | No | No | No | Yes | Yes |
| Observations | 4,023 | 2,682 | 562 | 7,203 | 1,868 | 1,727 |

Source: Authors'elaboration with data from Aboal and Garda (2012) , Álvarez et al. (2012), Gallego et al. (2013).
Notes: Results of a probit regression for Chile, and a bivariate probit regression, with technological and non-technological innovation as dependant variables, for Colombia and Uruguay. Marginal effects are reported in the case of Chile and Uruguay. Standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1

### 3.5 Innovation and Productivity

Finally, the results of the productivity equation are presented in Table 7. The coefficients reported are elasticities or semi-elasticities, since the dependent variable is the logarithm of sale per employee. Technological innovations (product or process) have a positive and significant impact on productivity in services and manufacturing in all countries. The impact of technological innovation on labour productivity in the service industry ranges between 0.258 in Colombia and 1.177 in Uruguay. The relative comparison of these impacts, between service and manufacturing firms, also varies from country to country. In Chile, the impact of technological innovation in labour productivity in services accounts for 50% of the impact in manufacturing firms. This figure goes up to more than 200% in the case of Colombia.

In Colombia and Uruguay, the effect of non-technological innovation was estimated. Mixed results on the size, sign, and significance of the associated coefficient were found, somewhat contradicting the idea that non-technological innovation is consistently more important in services than technological innovation. In Uruguay, the coefficient of non-technological innovation is almost four times higher than the value of the technological innovation parameter in services. However, no statistically significant relationship between non-technological innovation and labour productivity was found in Colombia.

Firm size is negatively correlated with labour productivity in the service sector in all countries studied, and this effect is consistently more negative in service than in manufacturing firms.

For the purpose of a robustness check, the production equation was estimated, adding the predicted value of innovation investment rather than the predicted value of technological innovation. The main results reported here remain unchanged. These results can be found in Table B.1 in the Annexes.

**Table 7: The Impact of Technological Innovation on Labour Productivity**

| | Chile | | Colombia | | Uruguay | |
|---|---|---|---|---|---|---|
| | Services | Manufacturing | Services | Manufacturing | Services | Manufacturing |
| Log labour productivity (sales per employee) | | | | | | |
| TI_p | 0.737*** | 1.337*** | 0.258* | 0.110*** | 1.177* | 1.249*** |
| | (0.148) | (0.190) | (0.118) | (0.020) | (0.669) | (0.299) |
| EM | -0.321*** | -0.0123 | -0.138** | 0.123*** | -0.163*** | 0.261*** |
| | (0.019) | (0.033) | (0.047) | (0.012) | (0.034) | (0.043) |
| KE | n.a. | n.a. | 0.237*** | 0.288*** | 0.072** | 0.208*** |
| | | | (0.023) | (0.024) | (0.030) | (0.065) |
| NTI | … | … | 0.166 | 0.188*** | 4.315*** | -5.412*** |
| | | | (0.124) | (0.042) | (0.889) | (1.292) |
| Both | … | … | … | … | 1.358*** | -1.006*** |
| | | | | | (0.297) | (0.290) |
| Constant | 11.000*** | 10.140*** | … | … | 12.950*** | 12.510*** |
| | (0.129) | (0.0952) | | | (0.172) | (0.176) |
| INFO | No | No | No | No | Yes | Yes |
| ISIC Dummy | No | No | No | No | Yes | Yes |
| Observations | 4,023 | 2,688 | 562 | 7,203 | 1,093 | 1,209 |

Source: Authors' elaboration with data from Aboal and Garda (2012), Álvarez et al. (2012), and Gallego et al. (2013).
Notes: Bootstrapped standard errors in parentheses (100 replications). ***p<0.01, **p<0.05, *p<0.1.

## 4. Conclusion

This paper has presented a comparison analysis between econometric research studies from three LAC countries, applying the CDM model to study the determinants of innovation and productivity in the service sector. The CDM model allows separation and understanding of the drivers of decisions of firms that invest in innovation, innovation output, and the impacts of technological innovation on labour productivity. The analysis was based on a comparison between the results of the model applied to service firms and manufacturing firms in each country.

The study finds strong evidence of a positive relationship between innovation inputs and outputs, and between innovation outputs and labour productivity in the service sector, across countries. These results are comparable to the results in manufacturing firms in LAC countries and are consistent with evidence from industrialized countries. Service firms are as innovative as manufacturing firms in LAC countries, and their productivity could also be boosted through the introduction of technological innovations.

Two important consistent findings emerge. One is that firm size is less relevant in the decision whether to engage in innovation activities in services than in manufacturing, suggesting an opportunity to increase aggregated service productivity by supporting service SMEs. Second, cooperation for innovation seems more important for services than for manufacturing at the moment of implementing innovation projects. This is related to the intangible nature of services and the importance of fostering user-producer linkages to stimulate innovation in this sector. Cooperation is also a signal that spillovers could be more widespread in services than in manufacturing. However, the service industry is receiving proportionately less public support to innovate than manufacturing firms.

Despite these similarities between the main patterns of innovation in services and manufacturing, differences in relevant explanatory variables and size of the effects arise in the comparison among countries, suggesting that framework conditions where a firm operates play an important role affecting innovation decisions of the firm. This topic deserves further research.

Finally, some comparability problems stem from differences in the coverage and design of innovation surveys in LAC countries. Improvements in the degree of comparability, homogeneity of sample designs, and industries covered in innovation surveys will deepen and improve the quality of analysis of service firm dynamics.

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## Annex A. Variables and Definitions

| Variable | | Chile | Colombia | Uruguay |
|---|---|---|---|---|
| Exporting | EX | Dummy equals 1 if firm exports at the beginning of the period | Dummy equals 1 if firm exports at the beginning of the period | Dummy equals 1 if firm exports at the end of the period |
| Foreign ownership | FO | Dummy equals 1 if foreign capital ownership is above 0% at the beginning of the period | Dummy equals 1 if foreign capital ownership is above 0% at the beginning of the period | Dummy equals 1 if foreign capital ownership is above 10% at the beginning of the period |
| Size | EM | Log of number of employees at the beginning of the period | Log of number of employees at the beginning of the period | Log of number of employees at the end of the period |
| Patent protection | PA | Dummy equals 1 if firm filed for patent in the previous period | Dummy equals 1 if firm obtained a patent in the period | Dummy equals 1 if firm filed for patent in the period |
| Public financial support | FIN | Dummy equals 1 if firm received public support to finance innovation activities | Dummy equals 1 if firm received public support to finance innovation activities | Dummy equals 1 if firm received public support to finance innovation activities |
| R&D | RD | … | Dummy equals 1 if firm has an R&D department. | … |
| Co-operation in innovation activities | CO | Dummy equals 1 if firm cooperate with other institution for innovation activities | Dummy equals 1 if firm cooperate with other firms for innovation activities | Dummy equals 1 if firm cooperate with other institution for R&D |
| Market information sources | INFO1 | Score measuring the importance of suppliers, clients, competitors, consulting firms, and experts | Dummy equals 1 if suppliers, clients, competitors, consulting firms, and experts, were important for innovation | Dummy equals 1 if suppliers, clients, competitors, consulting firms, and experts, were very important for innovation |
| Scientific information sources | INFO2 | Score measuring the importance of universities, public research centre, technological institutions | Dummy equals 1 if universities, public research centre, technological institutions were important for innovation | Dummy equals 1 if universities, public research centre, technological institutions were very important for innovation |
| Other | INFO3 | Score measuring the importance of journals, patents, magazines, expositions, associations, databases, internet. | Dummy equals 1 if journals, patents, magazines, expositions, associations, databases, internet, were important for innovation. | Dummy equals 1 if journals, patents, magazines, expositions, associations, databases, internet, were very important for innovation. |

| | | | | |
|---|---|---|---|---|
| Capital per employee | EQ | Share of new equipment over total equipment expenditures, in the last 3 years. | Log of capital investment per employee | Total fixed assets per employee |
| Non Technological innovation | NTI | … | Dummy equal to one if firm introduced marketing or organizational innovation | Dummy equal to one if firm introduced marketing or organizational innovation |
| Decision to invest in innovation | ID | Dummy equals 1 if innovation expenditure is positive | Dummy equals 1 if innovation expenditure is positive | Dummy equals 1 if innovation expenditure is positive |
| Innovation expenditures | IE | Log innovation expenditure per employee | Log innovation expenditure per employee | Log innovation and learning expenditure per employee |
| Predicted innovation expenditure | IE_p | Predicted value of innovation intensity | Predicted value of innovation intensity | |
| Technological innovation | TI | Dummy equal to one if firm introduced product or process innovation | Dummy equal to one if firm introduced product or process innovation | Dummy equal to one if firm introduced product or process innovation |
| Predicted technological innovation | TI_p | Predicted value of technological innovation | Predicted value of technological innovation | Predicted value of technological innovation |
| Productivity | Y | Log of sales per employee | Added value per employee | Log of sales per employee |

## Annex B. Robustness Check of the Impact of Technological Innovation on Labour Productivity

Table B.1: The Impact of Technological Innovation on Labour Productivity

| | Chile | | Colombia | | Uruguay | |
|---|---|---|---|---|---|---|
| | Services | Manufacturing | Services | Manufacturing | Services | Manufacturing |
| Log labour productivity (sales per employee) | | | | | | |
| IE_p | 0.384*** | 0.736*** | 0.268*** | 0.509*** | 0.489*** | 0.471*** |
| | (0.045) | (0.055) | (0.082) | (0.025) | (0.076) | (0.097) |
| EM | -0.305*** | -0.035 | -0.135** | 0.059*** | -0.059*** | 0.188*** |
| | (0.015) | (0.028) | (0.045) | (0.011) | (0.021) | (0.030) |
| KE | n.a. | n.a. | 0.231*** | 0.286*** | 0.070** | 0.210*** |
| | | | (0.023) | (0.023) | (0.030) | (0.051) |
| Constant | 10.260*** | 7.367*** | … | … | 12.840*** | 11.310*** |
| | (0.140) | (0.194) | | | (0.124) | (0.273) |
| INFO | No | No | No | No | Yes | Yes |
| ISIC | No | No | No | No | Yes | Yes |
| Observations | 4,023 | 2,688 | 562 | 7,203 | 1,093 | 1,209 |

Source: Authors' elaboration with data from Aboal and Garda (2012), Álvarez et al. (2012) and Gallego et al. (2013).
Note: Bootstrapped standard errors in parentheses (when reported) (100 replications). ***p<0.01, **p<0.05, *p<0.1.

**UNU-MERIT Working Papers**

**ISSN 1871-9872**

**Maastricht Economic and social Research Institute on Innovation and Technology, UNU-MERIT**

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